Agilent U9391C/F/G Comb Generator

Operating and Service Manual

Agilent Technologies

Notices

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1 Introduction

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"Compatible Agilent Network Analyzer" on page 11
"Options" on page 11
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This chapter provides an overview specifications of the Agilent U9391C/F/G Comb Generator.

Product Overview

The U9391C/F/G comb generator was designed as a phase reference standard for the Agilent PNA-X nonlinear vector network analyzer (NVNA). It was developed to provide precision phase calibration, referenced to the National Institute of Standards and Technology (NIST).

NVNA component characterization software converts a 4-port PNA-X with option 510 into an innovative, high-performance, non-linear network analyzer which uses U9391C/F/G comb generators as precision phase calibration standards. Comb generators generate frequency harmonics at integer multiples of an RF input signal.

Generally, comb generators available in the open market today are made with SRD diodes, U9391C/F/G comb generators are based on Agilent InP MMIC technology to ensure superior phase stability of the combs.

Figure 1-1 U9391C Comb Generator

Figure 1-2 U9391F Comb Generator

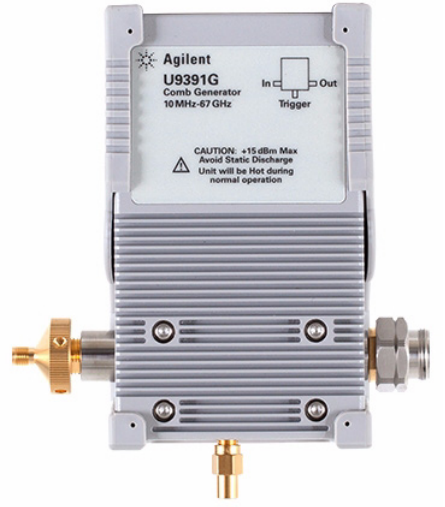

Figure 1-3 U9391G Comb Generator

The U9391C/F/G comb generator offers the advantage of wide bandwidth 10MHz to 26.5GHz, 10MHz to 50GHz, and 10MHz to 67GHz output and small minimum tone spacing (10MHz). When driven by low phase noise sources, this comb generator will operate at frequencies lower than 10MHz, but performance is not guaranteed. The input power and fundamental frequency have lower sensitivity than other comb generators. This means a comb generator calibrated at a single power level and frequency can be used across a wide range of input power. It comes with the option of a female or male output connector.

U9391C/F/G modules are solid state devices which provide excellent phase and amplitude flatness in the combs making them ideal for use in phase calibration applications. A built-in frequency divider, selectable via the PNA-X, reduces the noise of the combs. You can set drive frequency at 1, 2, 4, 8 or 16 times the pulse repetition frequency (PRF). Combining a frequency divider with a wide input signal frequency range allows for a broad range of possible harmonics spacing, making this suitable for characterizing non-linear devices. This module has a trigger output which enables synchronization with the pulse's repetition frequency. Calibration data stored inside the U9391C/F/G can be accessed directly by the PNA-X via the USB interface to be used in phase calibration.

Key Features of Agilent U9391C/F/G Comb Generator

- Excellent amplitude and phase flatness enable it to be used as a precision calibration phase reference standard for the NVNA.
- NIST referenced phase calibration guarantees a reliable reference to international standards.
- Embedded calibration data can be easily accessed via the plug-and-play USB interface.
- The USB interface further facilitates frequency divider control and calibration data retrieval via the PNA-X.

- Rugged 1.85mm, 2.4mm, and 3.5mm bulk-head connectors guarantee high repeatability throughout multiple connects and disconnects.
- The sine-to-square wave converter provided as standard accessory (U9391F/G only) ensures the comb generator functions at its optimum level for output frequencies above 26.5GHz.
- The hand grip (U9391G only) is designed for better gripping and as a heat insulator for user's handling.

Compatible Agilent Network Analyzer

The U9391C/F/G are designed to operate with Agilent PNA-X nonlinear vector network analyzer (NVNA). The U9391C/F/G modules are controlled by the PNA-X network analyzer via a USB connection with options required: 400, 419, 080, 510. PNA-X network analyzers can be upgraded to perform non-linear component characterization.

Options

There are two connector options available for Agilent U9391C/F/G.

Table 1-1 Options for Agilent U9391C/F/G

Option	U9391C	U9391F	U9391G
Option FF**F**	3.5mm Female (Output connector)	2.4mm Female (Output connector)	1.85mm Female (Output connector)
Option FF**M**	3.5mm Male (Output connector)	2.4mm Male (Output connector)	1.85mm Male (Output connector)

NOTE The Trigger and Input ports are of **3.5mm** Female connectors, for all the options above.

Service and Recertification

If your Comb generator modules require service or recertification, contact the nearest Agilent office for information on where to send it. Refer to " Contacting Agilent" in the front matter of this manual. The performance of the comb generator modules can only be verified by specially manufactured equipment and calibration standards from Agilent.

Recertification of Comb Generator Modules

The suggested interval for recertification is 12 months. After reviewing the result of the initial recertification, you may establish a shorter interval that reflects greater use and wear of the module.

2 Installation

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"ESD Damage" on page 16
"Connector Care" on page 17
Comb Generator and Agilent PNA-X Configurations 18
"Alternative Configuration with Squaring Circuit" on page 19

This chapter provides you important information on how to check and prepare your instrument for operation.

Initial Inspection

1. Unpack and inspect the shipping container and its contents throughly to ensure that nothing was damaged during shipment. If the shipping container or cushioning material is damaged, the contents should be checked both mechanically and electrically.
   - Check for mechanical damage such as scratches or dents
   - Procedures for checking electrical performance are given under "Operator's Check" on page 36.
2. If the contents are damaged or defective, contact your nearest Agilent Technologies Service and Support Office. Refer to the Service and Support information in the front matter of this manual. Agilent Technologies will arrange for repair or replacement of the damaged or defective equipment. Keep the shipping materials for the carrier's inspection.
3. If you are returning the instrument under warranty or for service, repackaging the instrument requires original shipping containers and material or their equivalents. Agilent Technologies can provide packaging materials identical to the original materials. Refer to Service and Support information in the front matter of this manual for the Agilent Technologies nearest to you. Attach a tag indicating the type of service required, return address, model number and serial number. Mark the container ***FRAGILE*** to insure careful handling. In any correspondence, refer to the instrument by model number and serial number.

Kit Contents

The following table lists the items in the U9391C/F/G kit.

Table 2-1 U9391C/F/G Kit Contents

QUANTITY	DESCRIPTION	PART NUMBER
1	Cable assembly - Banana plug*	U9391-20013
1	USB cable	8121-0506

* Compatible cable: 87405-20006

Operating and Safety Precautions

Observe the following guidelines before connecting or operating the Comb Generator modules.

ESD Damage

Protection against electrostatic discharge (ESD) is important while handling and operating the Agilent U9391C/F/G module.

Static electricity can build up on your body and can easily damage sensitive components when discharged.

Static discharges too small to be felt can cause permanent damage to the unit.

To prevent damage from ESD:

- ***Use*** a grounded antistatic mat in front of your test equipment and wear a grounded wrist strap attached to it when handling or operating the Comb Generator module.
- ***Wear*** a heel strap when working in an area with a conductive floor.
- ***Ground*** yourself before you clean, inspect or make a connection to an Comb Generator module. You can, for example, grasp the grounded outer shell of the analyzer test port or cable connector briefly.
- ***Avoid*** touching the center conductor of the test ports.

Connector Care

Because connectors can become defective due to wear during normal use, all connectors should be inspected and maintained to maximize their service life.

• **Inspect** the mating surface each time a connection is made. Metal particles from connector threads often find their way onto the mating surface when a connection is made or disconnected.

• **Clean** dirt and contamination from the connector mating surface and threads. This simple step can extend the service life of the connector and improve the quality of your calibration and measurements.

• **Gage** connectors periodically. This not only provides assurance of proper mechanical tolerances, and thus connector performance, but can also indicate situations where the potential for damage to another connector may exist.

CAUTION The Agilent Comb Generator modules can be damaged if apply excessive torque to the connectors.

The recommended torque value is 8lb-in torque.

Comb Generator and Agilent PNA-X Configurations

Two units of U9391C/F/G are required to carry out non-linear measurements. One unit is used as the phase reference module and the second unit as the phase calibration module.

The U9391C/F/G units need to be powered by separate power supplies.

The NVNA software automatically controls the U9391C/F/G units via USB after the two units have been selected as the phase reference and phase calibration module respectively.

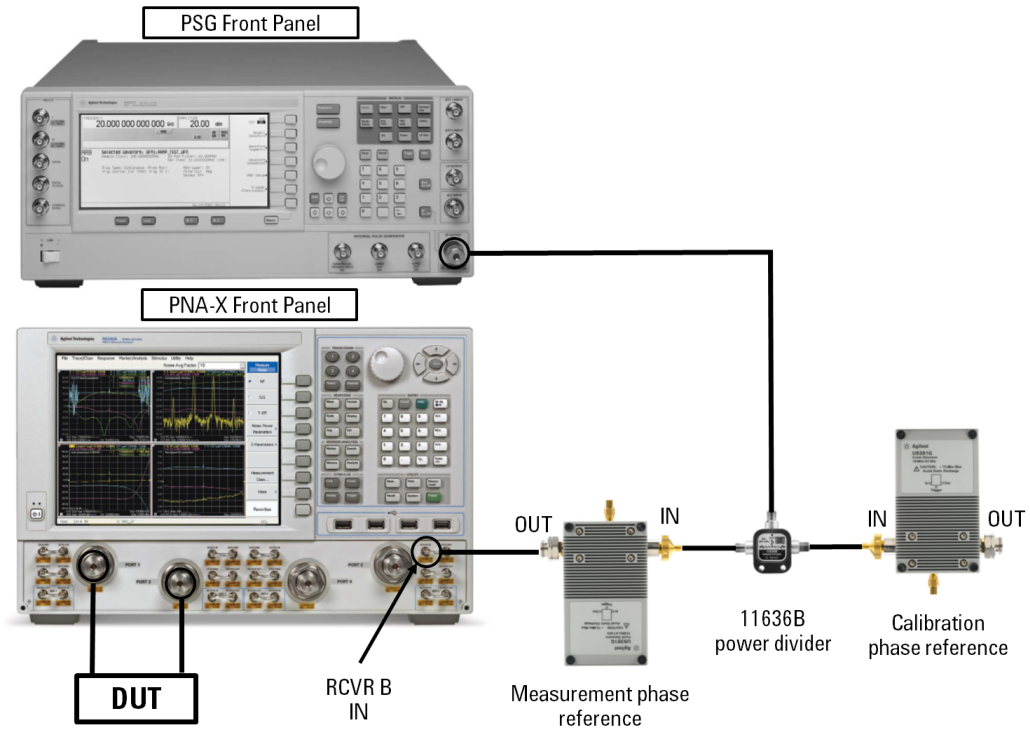

Figure 2-1 U9391C/F/G and PNA-X Configuration

The phase calibration procedure is carried out by following the on-screen instructions on the PNA-X.

After completing the calibration, the U9391C/F/G unit used for phase calibration can be disconnected. The other unit that is used as the phase reference will remain connected while the measurement is carried out.

For more detailed information, please refer to the Help file that is embedded in the NVNA application.

CAUTION When connecting the U9391C/F/G directly to the instrument test ports, the modules will require mechanical support so as not to overstress the test port connectors.

Alternative Configuration with Squaring Circuit

If a signal generator is not available, the PNA-X 10MHz reference output located at the back panel can be used as a signal source. However, the U9391-60009 sine-to-square wave converter is required as the comb generator will not function at its optimum level for output frequencies above 26.5GHz, with a sine wave input of less than 100MHz. Having said this, the converted 10MHz square wave signal may portray some reduced calibration accuracy, in comparison to using the PSG as a source.

Hence, the U9391-60009 squaring circuit, which is powered up via USB, is included as a standard accessory for U9391F and U9391G.

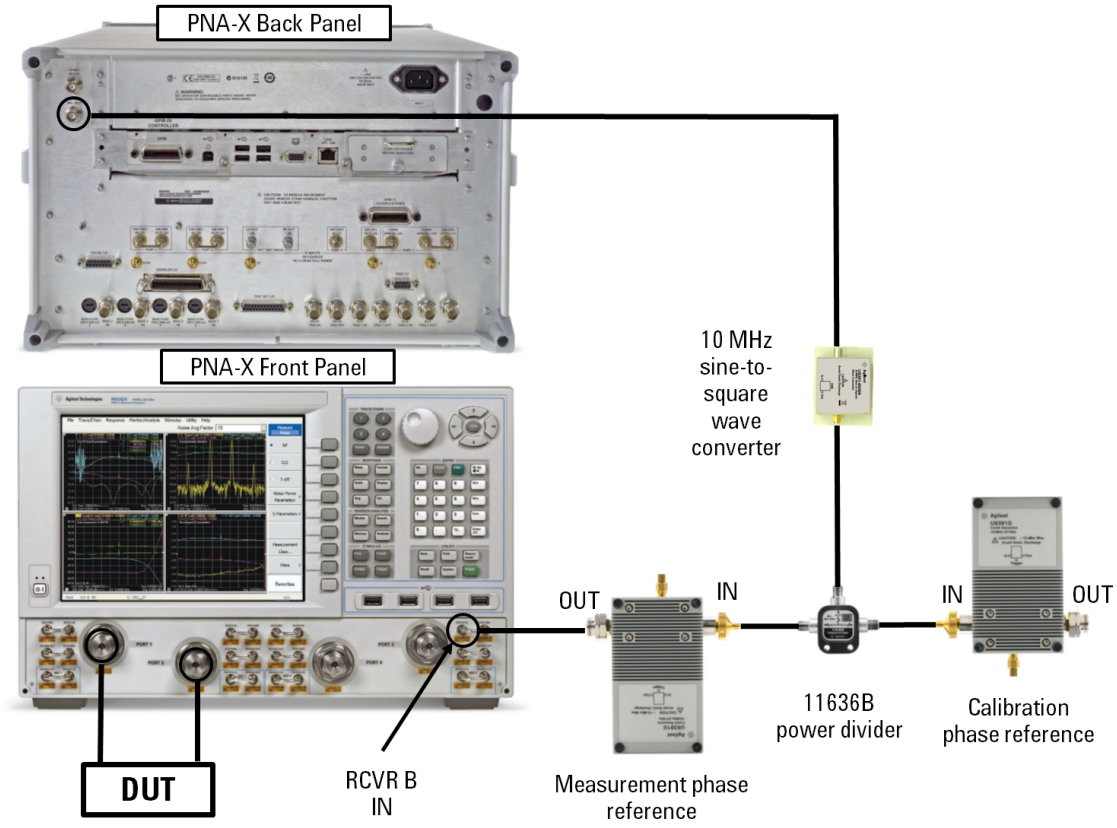

Figure 2-2 U9391F/G and Square Wave Converter Configuration

3 Specification

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This chapter provides an overview specifications of Agilent U9391C/F/G Comb Generator.

General Specifications

Drive Power Supply Specifications

Table 3-1 U9391C/F/G Drive Power Supply Specification

Model	U9391C	U9391F	U9391G
Voltage	+15 ± 10% Vdc	+15 ± 10% Vdc	+15 ± 10% Vdc
Current	300mA (nominal)	300mA (nominal)	850mA (nominal)

NOTE

Recommended DC power supply for U9391C/F: E3620A

Recommended DC power supply for U9391G: E3615A

Compatible DC power supply: All E36XXA series power supply (except E3612A and E3614A).

Current drawn will change when drive voltage changes.

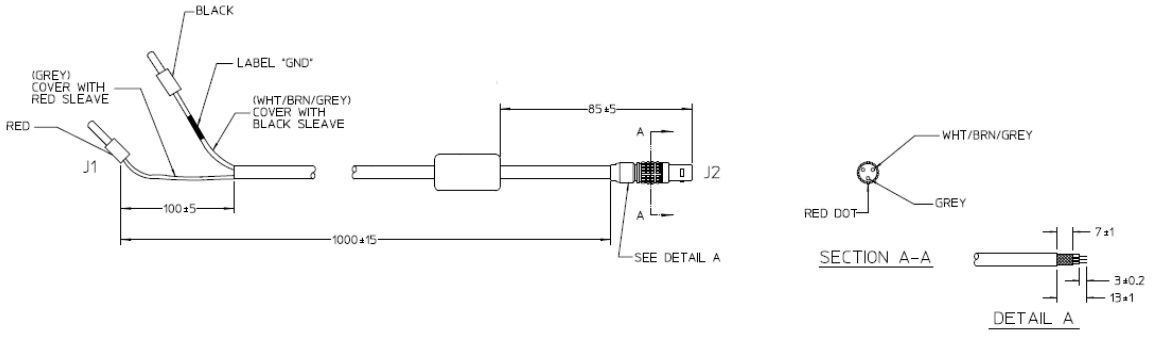


Figure 3-1 U9391-20013 DC Bias Cable

Physical Specifications

Model	U9391C	U9391F	U9391G
Net weight	0.370kg	0.370kg	0.435kg
Shipping weight	3.155kg	3.315kg	3.385kg
Shipping dimension			
Length	52.5cm	52.5cm	52.5cm
Width	34.0cm	34.0cm	34.0cm
Height	19.5cm	19.5cm	19.5cm

Specifications

Specifications refer to the performance standards or limits against which the U9391C/F/G are tested.

Typical characteristics are included for additional information only and they are not specifications. These are denoted as "typical", "nominal", or "approximate" and are printed in italic.

Table 3-2 U9391C/F/G Specifications

Model	U9391C	U9391F	U9391G
Output frequency range*	10MHz to 26.5GHz	10MHz to 50GHz	10MHz to 67GHz
Input frequency range†	10MHz to 6GHz	10MHz to 6GHz	10MHz to 6GHz
Input power range	-15 to +15dBm	-15 to +15dBm	-15 to +15dBm
Min output power per picket	-80dBm at 10MHz Input PRF	-95dBm at 10MHz Input PRF	-100dBm at 10MHz Input PRF
Amplitude flatness vs. Output frequency	< 12dB at 10MHz Input PRF	< 25dB at 10MHz Input PRF	< 40dB at 10MHz Input PRF
Amplitude flatness vs. input power	*0.1dB (typical)*	*0.5dB (typical)*	*1.0dB (typical)*

Table 3-2 U9391C/F/G Specifications

Model	U9391C	U9391F	U9391G
Phase flatness‡	+/- 8.5 degrees (10MHz to 3GHz) +/- 6.5 degrees (3GHz to 20GHz) +/- 8.5 degrees (20GHz to 26.5GHz)	+10/-10 degrees (10MHz to 28GHz) +20/-10 degrees (28GHz to 38GHz) +20/-15 degrees (38GHz to 50GHz)	+10/-10 degrees (10MHz to 26.5GHz) +20/-10 degrees (26.5GHz to 38GHz) +20/-15 degrees (38GHz to 50GHz) +35/-35 degrees (50GHz to 67GHz)
Pulse width (ps)	< 23	< 23	< 23
Divide ratio	1, 2, 4, 8, 16	1, 2, 4, 8, 16	1, 2, 4, 8, 16
Input Return Loss, S11	> 10dB (10MHz to 6GHz)	> 10dB (10MHz to 6GHz)	> 10dB (10MHz to 6GHz)
Output Return Loss, S22	> 10dB (10MHz to 26.5GHz)	> 10dB (10MHz to 20GHz) > 7dB (20GHz to 45GHz) > 5dB (45GHz to 50GHz)	> 10dB (10MHz to 20GHz) > 7dB (20GHz to 45GHz) > 5dB (45GHz to 67GHz)

* When driven by low phase noise sources, this comb generator will operate at frequencies lower than 10MHz, but performance is not guaranteed.

† For operations below 100MHz, use a square wave to drive the comb generator.

‡ The specifications refers to the raw performance data. For NVNA application, the phase performance is corrected with the calibration data.

Mechanical Characteristic

Mechanical characteristics, such as center conductor protrusion and pin depth are not warranted performance specifications.

They are however important supplemental characteristics related to the electrical performance of the devices.

Agilent Technologies verifies the mechanical characteristics of the devices with special gaging processes and electrical testing.

These processes ensure that the device connectors do not exhibit any excess center conductor protrusion or improper pin depth when the module leaves the factory.

Pin Depth

Pin depth is the distance the center conductor mating plane differs from being flush with the outer connector mating plane.

The pin depth of a connector can be in one of two states: protrusion or recession.

Protrusion occurs when the center conductor extends beyond the outer conductor mating plane. It reads as a positive value on the connector gage.

Recession occurs when the center conductor is set back from the outer conductor mating plane. It reads as a negative value on the gage.

The pin depth for a 1.85mm, 2.4mm, and 3.5mm connector is shown in Figure 3-2.

The typical pin depths for U9391C/F/G connectors are listed in "Typical Pin Depth Values" on page 27.

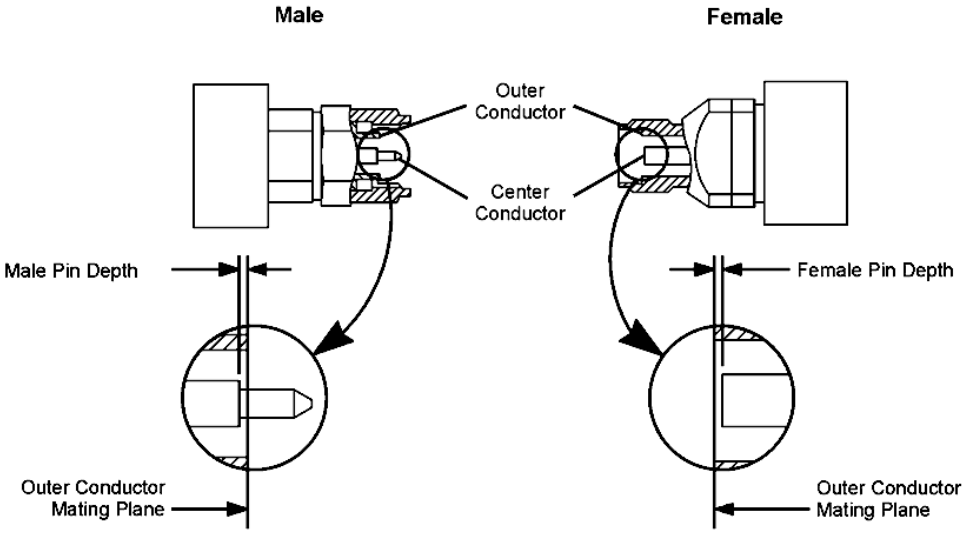


Figure 3-2 Pin Depth for a 1.85mm, 2.4mm, and 3.5mm Connectors

Typical Pin Depth Values

The pin depth value of each device is not specified, but is an important mechanical parameter.

The electrical performance of the device depends, to some extent, on its pin depth.

The electrical specifications for each module takes into account the effect of pin depth on the device's performance.

The following tables list the typical pin depths for the devices.

Table 3-3 U9391C/F/G Comb Generator Pin Depth Characteristic

Port	Typical Pin Depth in Micrometers (10^{-4} inches)		
	U9391C	U9391F	U9391G
In port	0 to -50.8 (0 to -20.0)	0 to -50.8 (0 to -20.0)	0 to -50.8 (0 to -20.0)
Out port	0 to -50.8 (0 to -20.0)	0 to -50.8 (0 to -20.0)	0 to -50.8 (0 to -20.0)
Trigger port	0 to -127.0 (0 to -50.0)	0 to -127.0 (0 to -50.0)	0 to -127.0 (0 to -50.0)

If the pin depth of a device does not measure within the observed pin depth limits, it may be an indication that the device fails to meet electrical specification.

Mechanical Dimension of the Modules

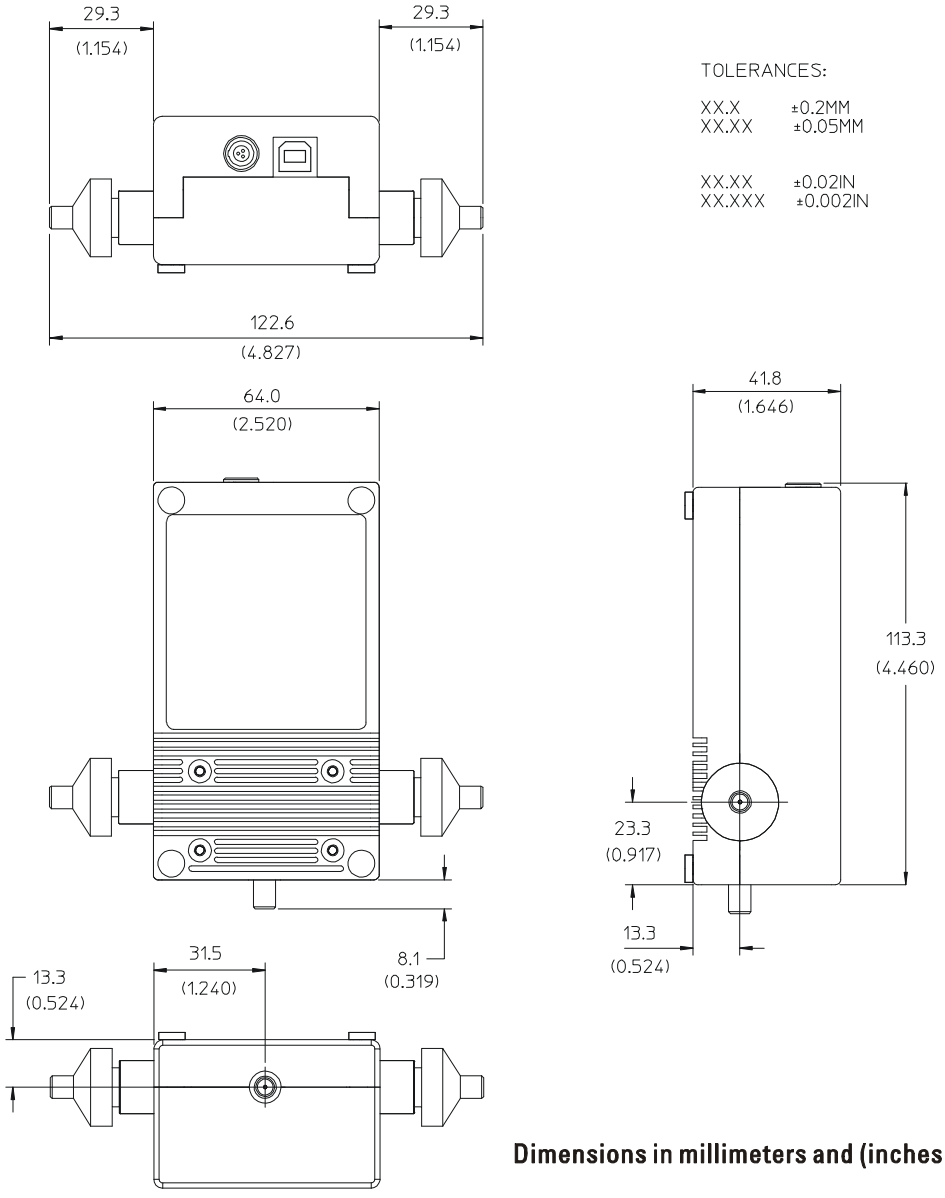
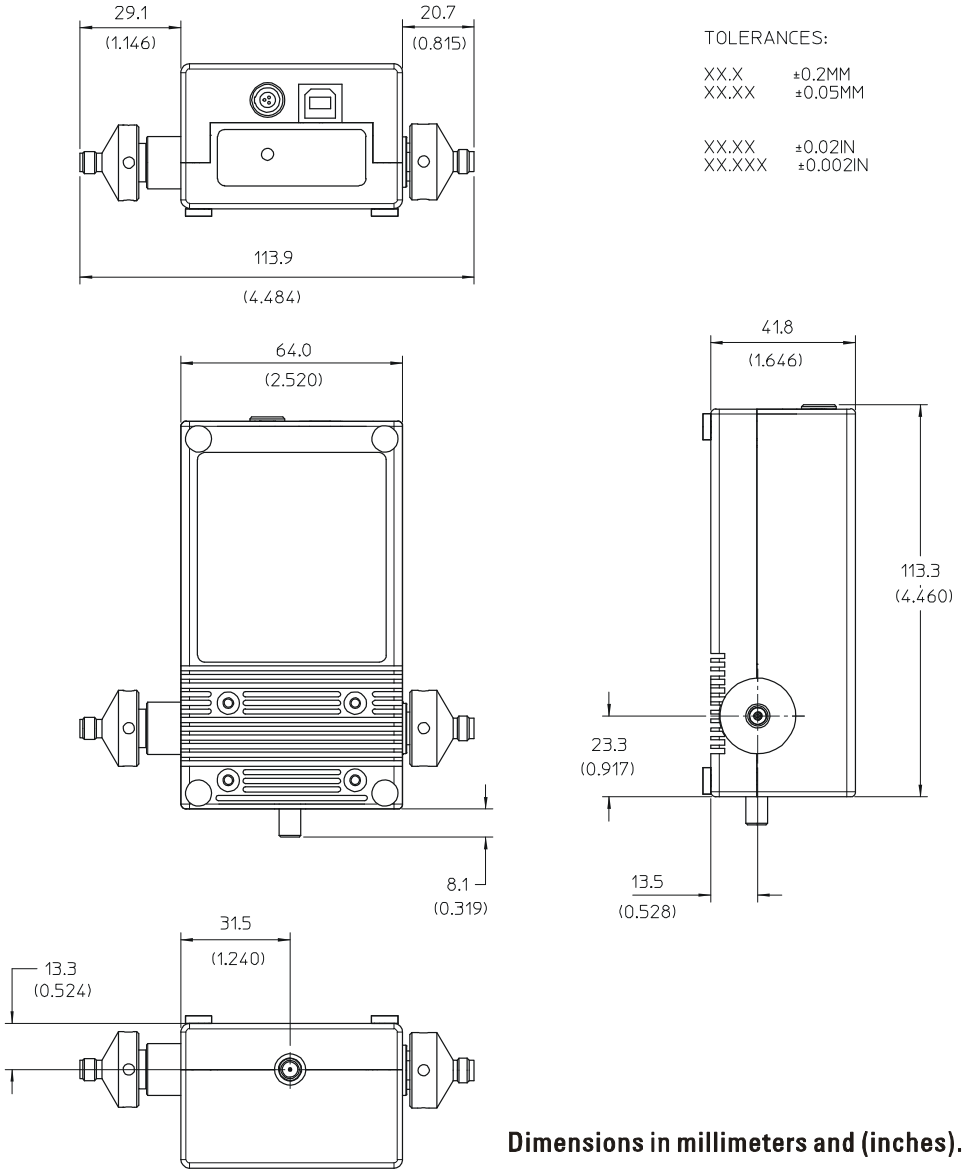


Figure 3-3 Mechanical Dimension of U9391C Comb Generator

Mechanical Dimension of the Modules



Dimensions in millimeters and (inches).

Figure 3-4 Mechanical Dimension of U9391F Comb Generator

Mechanical Dimension of the Modules

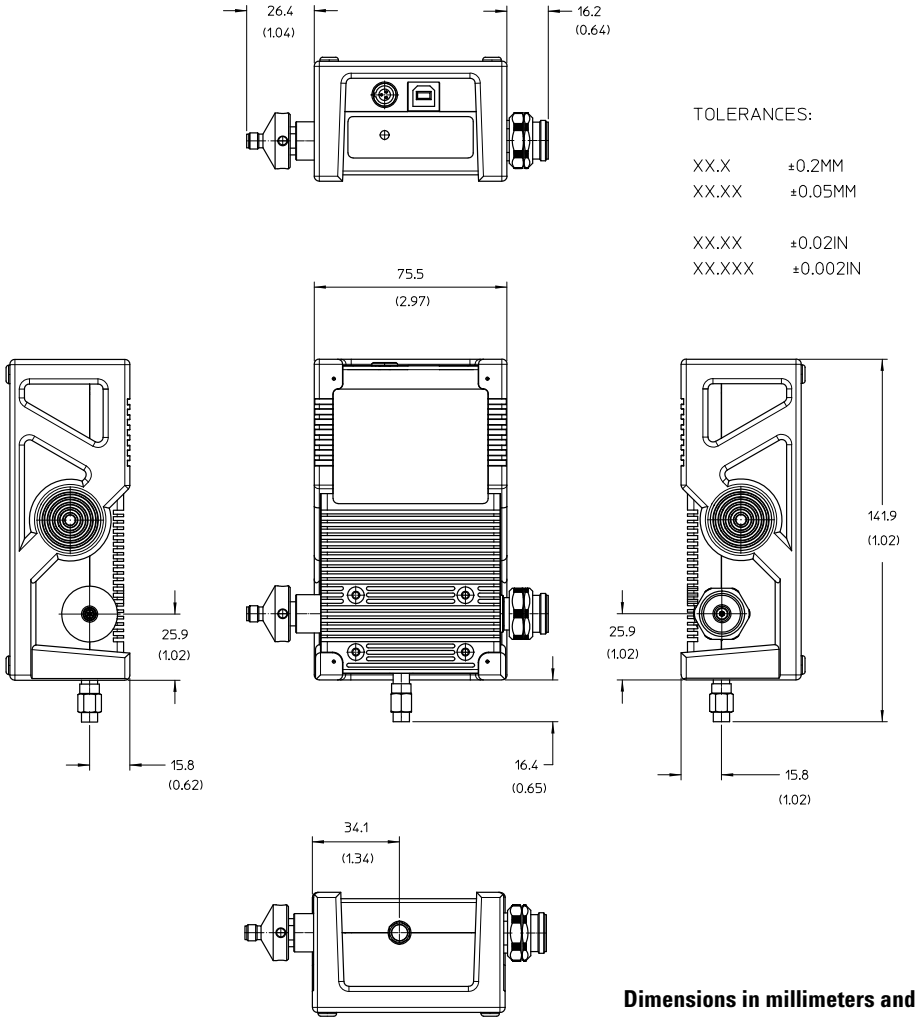
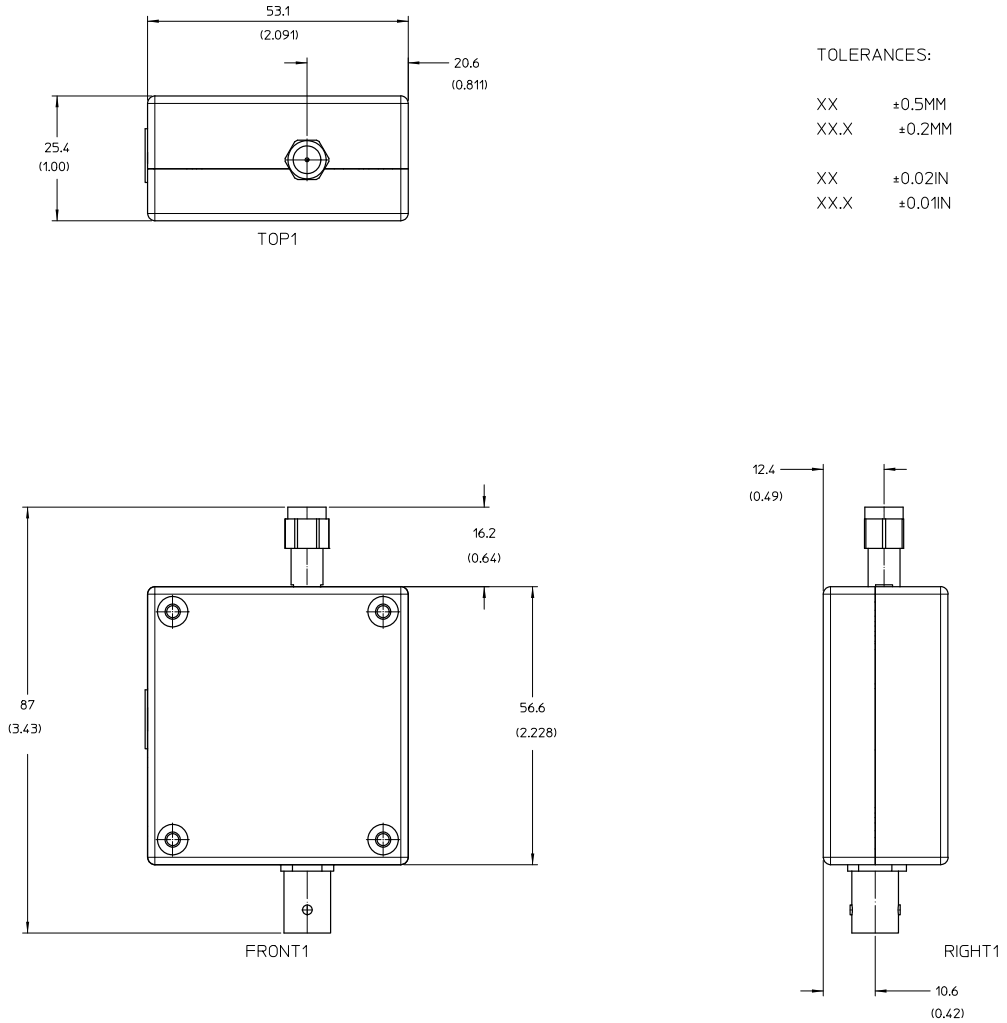


Figure 3-5 Mechanical Dimension of U9391G Comb Generator

NOTE The hand grip is designed for the U9391G only for better gripping and as a heat insulator for user's handling.

Mechanical Dimension for Squaring Circuit



Dimensions in millimeters and (inches).

Figure 3-6 Mechanical Dimension of U9391-60009 Squaring Circuit

NOTE The U9391-60009 squaring circuit is available for the U9391F and U9391G only.

Environmental Specifications

Agilent U9391C/F/G are designed to fully comply with Agilent Technologies's product operating environment specifications. The following are the summarized environmental specifications for these products.

Table 3-4 U9391C/F/G Environmental Specifications

Temperature	
• Operating	0°C to +40°C
• Storage	-40°C to +70°C
• Error corrected range	23°C to +/- 3°C
• Cycling	-65°C to +85°C, 10 cycles at 20°C per minute. 20 minutes dwell time per MIL-STD-883F, Method 1010.8, Condition C (modified)
Relative Humidity	
• Operation	50% to 95% RH at 40°C, 24 hours cycling, repeated 5 times
• Storage	90% RH at 65°C, one 24 hour cycle
Shock	
• End-use handling shock	Half-sine wave form, 2-3ms duration, 60 in/s (1.6ms) delta-V
• Transportation shock	Trapezoidal wave form, 18-22ms duration, 337 in/s (8.56ms) delta-V
Vibration	
• Operating	Random: 5-500Hz, 0.21grms, 10min/axis
• Survival	Random: 5-500Hz, 2.09grms, 10min/axis Swept Sine: 5-500Hz, 0.5grms, 10min/axis, 4 resonance search, 10min dwell
Altitude	
• Operating	< 4,572 meters (15,000 feet)
• Storage	< 15,000 meters (50,000 feet)
ESD immunity:	
• Direct discharge*	8.0 kV per IEC 61000-4-2
• Air discharge	15 kV per IEC 61000-4-2

* To outer conductor

Compliance Notices and Regulatory Information

Compliance With Electromagnetic Compatibility (EMC)

This product conforms with the protection requirements of EMC Directive 2004/108/EC for Electromagnetic Compatibility.

The product comply to the EMC Directive by assessment according to IEC/EN61326-1 EMC standard.

In order to preserve the EMC performance of the product, any cable which becomes worn or damaged must be replaced with the same type and specifications.

Refer to the "Declaration of Conformity" on page 34.

Regulatory Markings

CE	The CE mark shows that the product complies with all the relevant European Legal Directives.
ICES/NMB-001	ICES/NMB-001 indicates that this ISM device complies with Canadian ICES-001. Cet appareill ISM est conforme a la norme NMB-001 du Canada.
ISM GRP.1 CLASS A	This is the symbol of an Industrial Scientific and Medical Group 1 Class A product.
N10149	The C-Tick mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australian EMC Framework Regulations under the terms of the Radio communications Act of 1992.

South Korean Class A EMC declaration:
This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home.

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Declaration of Conformity

A copy of the Manufacturer's Declaration of Conformity for this instrument can be obtained by contacting your local Agilent Technologies sales representative.

4
Operating Guides

Operating Instruction 36
"Operator's Check" on page 36
"Service Instructions" on page 44

This chapter provides you a simple quick-check instruction to verify Agilent U9391C/F/G Comb Generators' functionality prior to usage.

Operating Instruction

Operator's Check

The operator's check is supplied to allow the operator to make quick check of the comb generator prior to use or if a failure is suspected.

CAUTION ESD exceeding the level specified in **Table 3-4** or RF power applied is greater than the maximum specified as in **Table 3-2** may cause permanent damage to the device.

Operator's Check for S-Parameter Test

Recommended Test Equipment

Table 4-1 and Table 4-2 below lists the test equipment required for performance test verification. Equipment other than the recommended models can be used, provided minimum specifications are satisfied.

Table 4-1 Recommended Test Equipment

Instrument Type	Setting
PNA-X Network Analyzer* (option 400, 419, 080, 510)	PNA-X application • Start Frequency: 10MHz • Stop Frequency: 26.5GHz/50GHz/67GHz† • Power Level: -20dBm • No of points: 201
For U9391C/F: E3631A DC Power Supply	• Voltage: +15Vdc • Current: 2 x 0.3A‡
For U9391G: E3615A DC Power Supply	• Voltage: +15Vdc • Current: 2 x 0.85A**

* N5242A, N5244A, N5245A, and N5247A

† 26.5GHz for U9391C, 50GHz for U9391F, and 67GHz for U9391G

‡ To power up 2 units of U9391C/F

** To power up 2 units of U9391G

Quick-Check Procedure

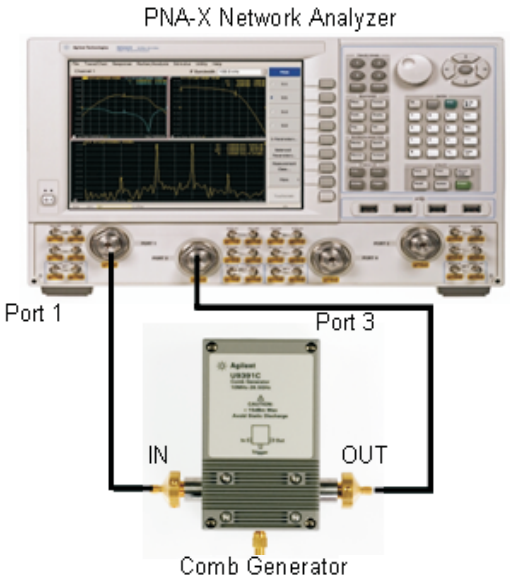

Figure 4-1 Quick-check Configuration for S-parameter Test

The equipment setup is as illustrated in Figure 4-1.

1. Click on PNA-X application. Calibrate the network analyzer with full 2-port calibration using the appropriate electronic or mechanical calibration kit.
2. Connect Input of comb generator to Port 1 of network analyzer and Output of comb generator to Port 2 of network analyzer.
3. Turn ON the biasing of the comb generator by connecting to power supply, +15V, 0.3A for U9391C/F and +15V, 0.85A for U9391G.
4. Get the measurement for Input Return Loss (S11) and Output Return Loss (S22).
5. Compare measurement results with specification in Table 3-2 on page 23.

Operator's Check for Nonlinear Vector Network Analyzer (NVNA) Test

Table 4-2 Recommended Test Equipment

Instrument Type	Setting
PNA-X Network Analyzer* (option 400, 419, 080, 510)	NVNA application • Start & Stop Frequency: 10MHz • Frequency points: 1 • Maximum Harmonics: 2650/5000/6700†
For U9391C/F: E3631A DC Power Supply	• Voltage: +15Vdc • Current: 2 x 0.3A‡
For U9391G: E3615A DC Power Supply	• Voltage: +15Vdc • Current: 2 x 0.85A**
E8267D PSG Signal source or any source that can provide 10MHz to 6GHz RF output	• N/A
Power sensor and power meter	• N/A
11636B Power Divider	• N/A

* N5242A, N5244A, N5245A, and N5247A

† 2650 for U9391C, and 5000 for U9391F, and 6700 for U9391G

‡ To power up 2 units of U9391C/F

** To power up 2 units of U9391G

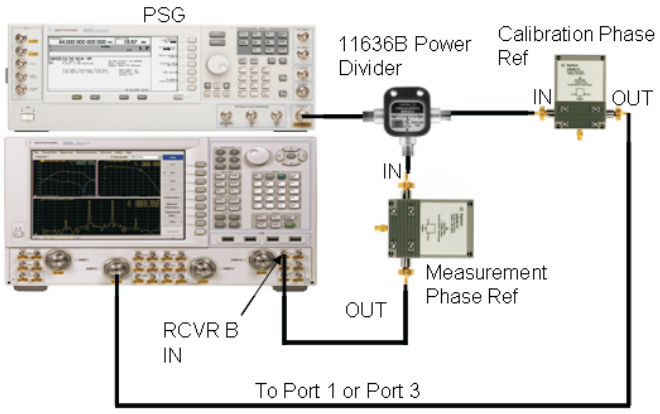

Figure 4-2 Quick-check Configuration for NVNA Test

Quick-Check Procedure

The equipment setup is as illustrated in Figure 4-2.

1. Connect GPIB linking PNA-X, PSG and Power Meter.
2. Power up both the phase reference units and also connect the USB cable to the PNA-X.
3. Shutdown the network analyzer application and turn on NVNA application. Leaving the network analyzer application running in the background will cause the NVNA applications to not function properly.
4. Click **Response** and select **Couple Segment** from Agilent Nonlinear Vector Network Analyzer main menu as shown in Figure 4-3.
5. Again, click **Response** and select **Receiver Attenuation**. Set 10dB at Receive B portion and then click **OK**.

6 Set the parameters as following. Then click **Apply** button.

- **a** Start and Stop frequency : 10MHz
- **b** Frequency points : 1
- **c** Maximum Harmonics : 2650/5000/6700*
- **d** IFBW : 10Hz

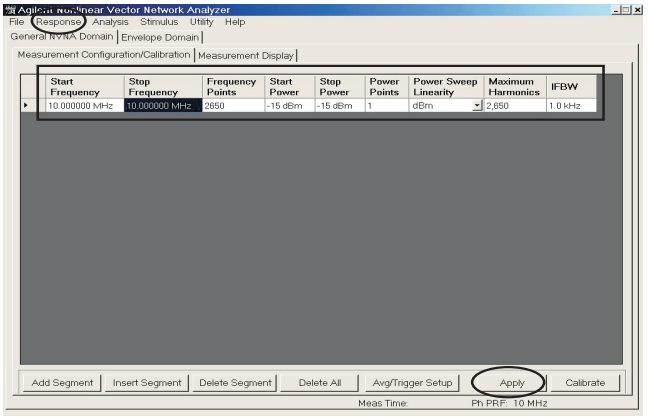

Figure 4-3 NVNA main menu

* 2650 for U9391C, 5000 for U9391F, and 6700 for U9391G

7 Click **Calibrate** button to start the NVNA Cal Wizard.

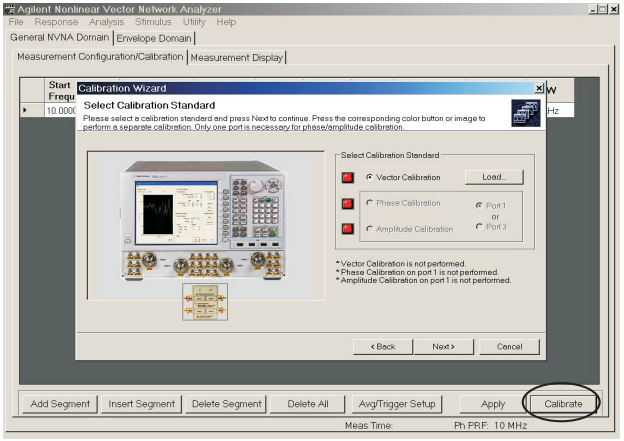

Figure 4-4 NVNA Calibration Wizard

8 Follow the on screen instruction on the PNA-X to perform calibration.

9 **Vector Calibration** must be performed first. Click **Load** to recall Cal Set data from a previously performed calibration. However, the stimulus settings for the Cal set must exactly match the current stimulus settings.

10 Select Port 1 or Port 3 and follow the instructions to perform the Amplitude Calibration using power sensor, before doing the Phase Calibration.

11 To perform **Phase Calibration**, select the phase reference unit that is identified to use for calibration. Then click **Next** button.

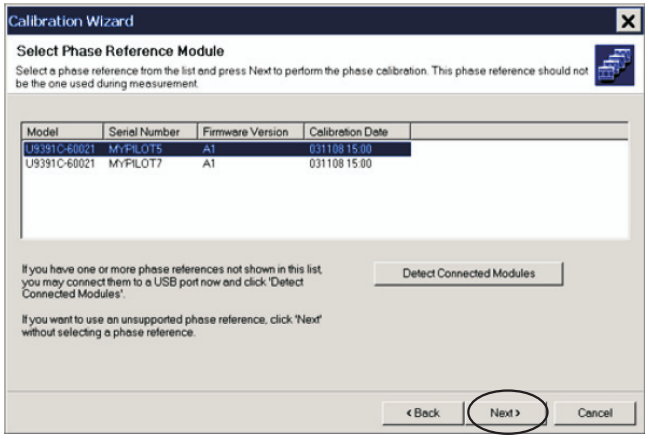
Calibration Wizard
Select Phase Reference Module
Select a phase reference from the list and press Next to perform the phase calibration. This phase reference should not be the one used during measurement.
Model
Serial Number
Firmware Version
Calibration Date
U9391C-60021 MyPILOT5 A1 031108 15:00
U9391C-60021 MyPILOT7 A1 031108 15:00
If you have one or more phase references not shown in this list, you may connect them to a USB port now and click 'Detect Connected Modules'.
If you want to use an unsupported phase reference, click 'Next' without selecting a phase reference.
Detect Connected Modules
< Back
Next >
Cancel

Figure 4-5 NVNA Calibration Wizard

12 Connect the **Output** of phase reference unit (unit that has been selected as phase calibration) to **Port 3** of network analyzer once calibration is completed.

13 Click on the **Measurement Display** tab and select as following to perform comb amplitude and comb phase measurement.

- **a** **Format** : select **Log Mag** (to measure comb amplitude) or **Phase** (to measure comb phase)
- **b** **Domain** : select **Frequency**
- **c** **Measure** : select **Single** or **Continuous**

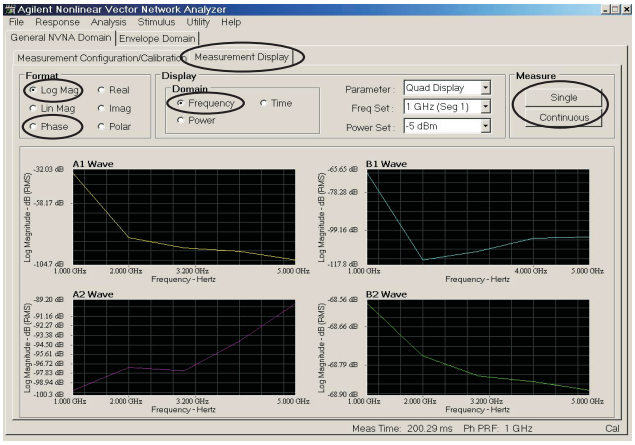

Figure 4-6 NVNA main menu

14 Compare measurement results with specification in Table 3-2 on page 23.

15 Phase measurement will fluctuate between +180 to -180 degrees due to phase wrapping.

Service Instructions

Repair

In case your comb generator module requires repair services, please contact your nearest Agilent Sales and Service Center.

Adjustment

The comb generator do not have internal adjustments and should not be opened.

Maintenance

The connectors, particularly the connector faces, must be kept clean. For instruction on connecting and care of your connectors, refer to the Microwave Connector Care Quick Reference Card (08510-90360).